

Information on Atmospheric Aerosol in OMI Measurements

Ben Veihelmann,
Pieterneel Levelt, Piet Stammes and Pepijn Veefkind
Royal Netherlands Meteorological Institute (KNMI)



EOS Aura Science and
Validation Team Meeting
11-15 September 2006
NCAR Center Green Facility –
Boulder, CO



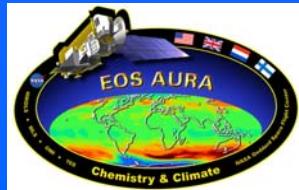
Overview

- Multi-wavelength aerosol algorithm
- Principal Component Analysis (PCA)
- Degrees of Freedom of Signal (DFS)
- Distinguish Aerosol Types
- Separate Aerosol Parameters
- Surface albedo
- Clouds



Information on Aerosol in OMI Measurements
Aura Science & Validation Team Meeting, September 2006
B.Veihelmann et al., KNMI

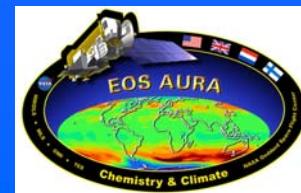
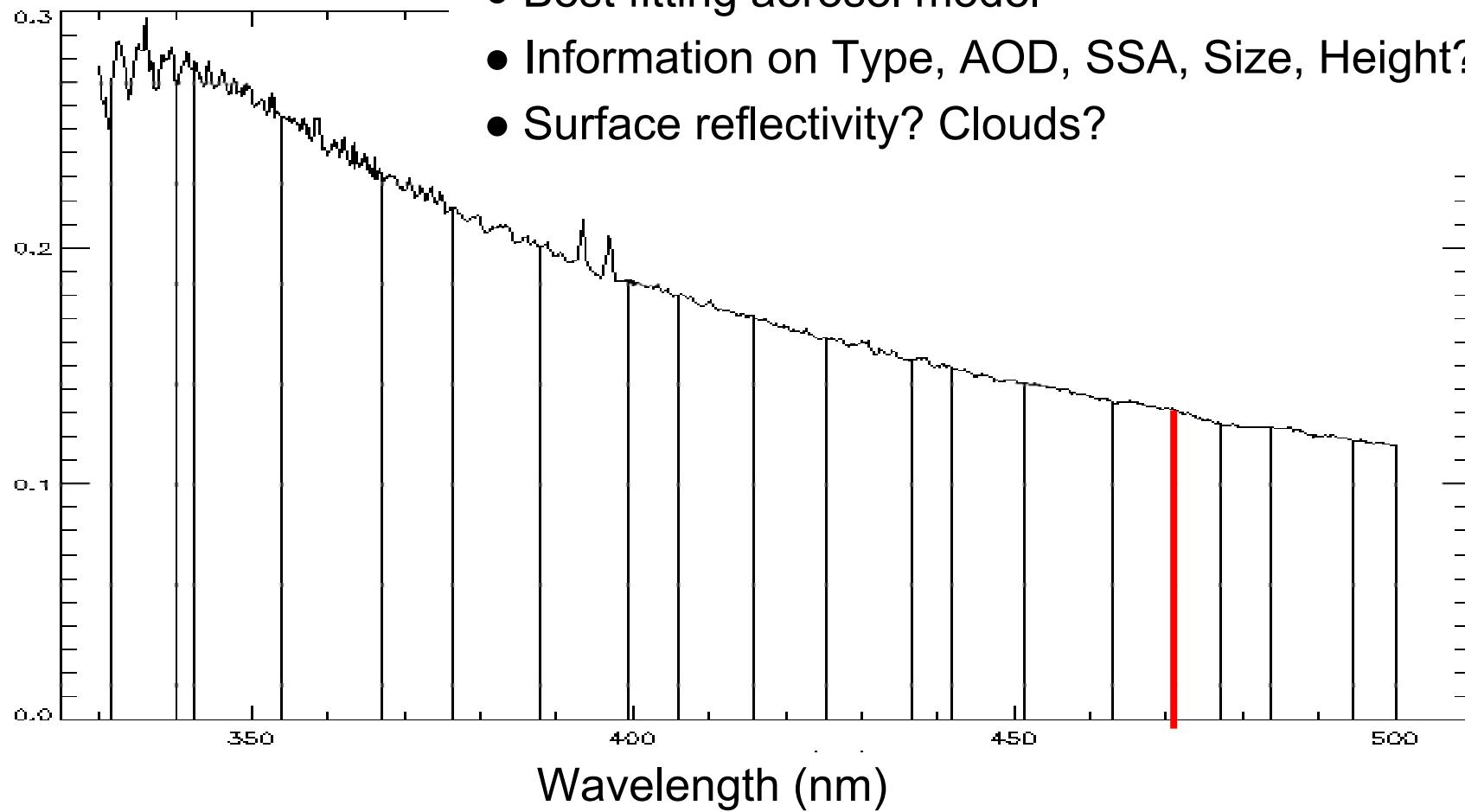
Slide 2



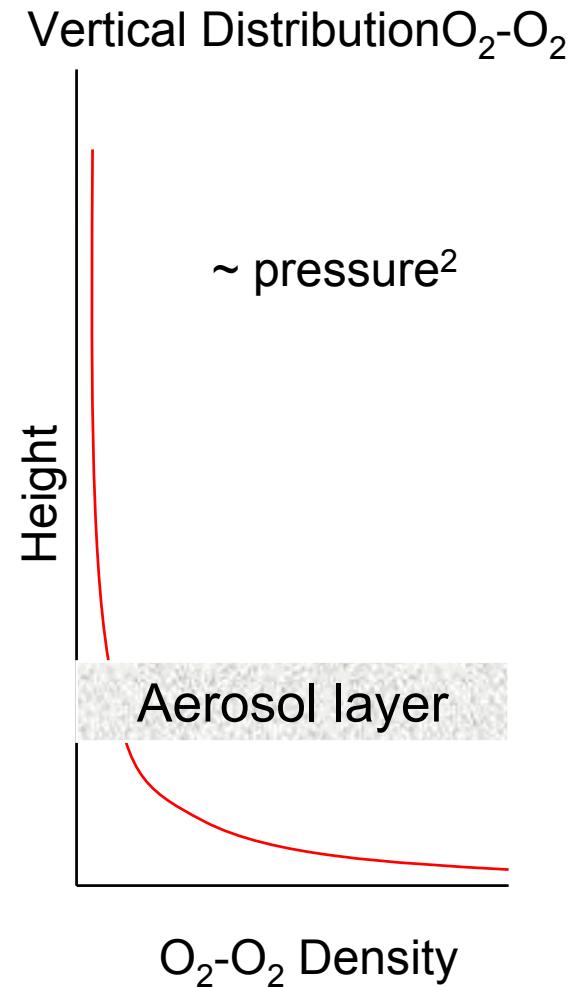
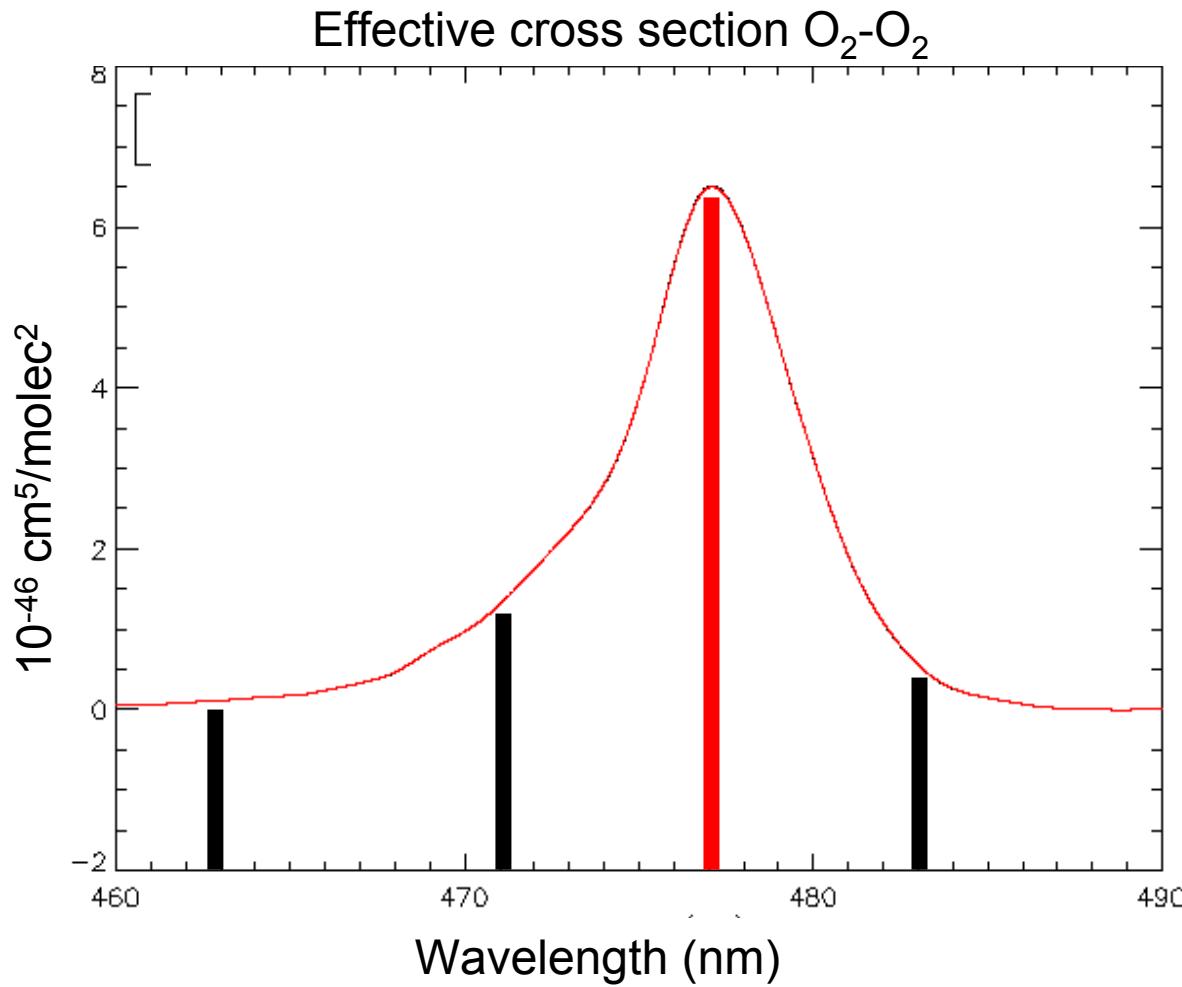
Multi-Wavelength Approach

- Best fitting aerosol model
- Information on Type, AOD, SSA, Size, Height?
- Surface reflectivity? Clouds?

Reflectance

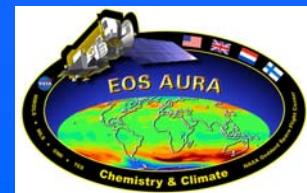


Height Information from 477 nm ?



Information on Aerosol in OMI Measurements
Aura Science & Validation Team Meeting, September 2006
B.Veihelmann et al., KNMI

Slide 4



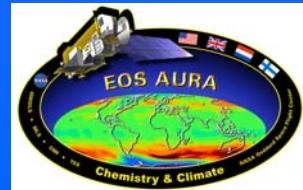
Principal Component Analysis

- R_{lm} = Reflectance(λ , Measurement)
- Covariance matrix $R^T R = P^T D P$
- **Principal components** $P_{kl} = p_k(\lambda)$
- Decompose R

$$R_{lm} = \sum_{k=1}^K W_{km} P_{kl} + \varepsilon$$

**K = Number of components necessary to reconstruct
 R with an error $\varepsilon < \varepsilon_{\text{noise}}$**

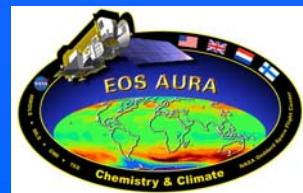
→ **Number of Degrees of Freedom of Signal**
→ **Set of K Weights W for a given measurement**



Synthetic Data

for Reflectance $R(\lambda, \text{model})$

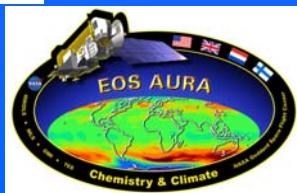
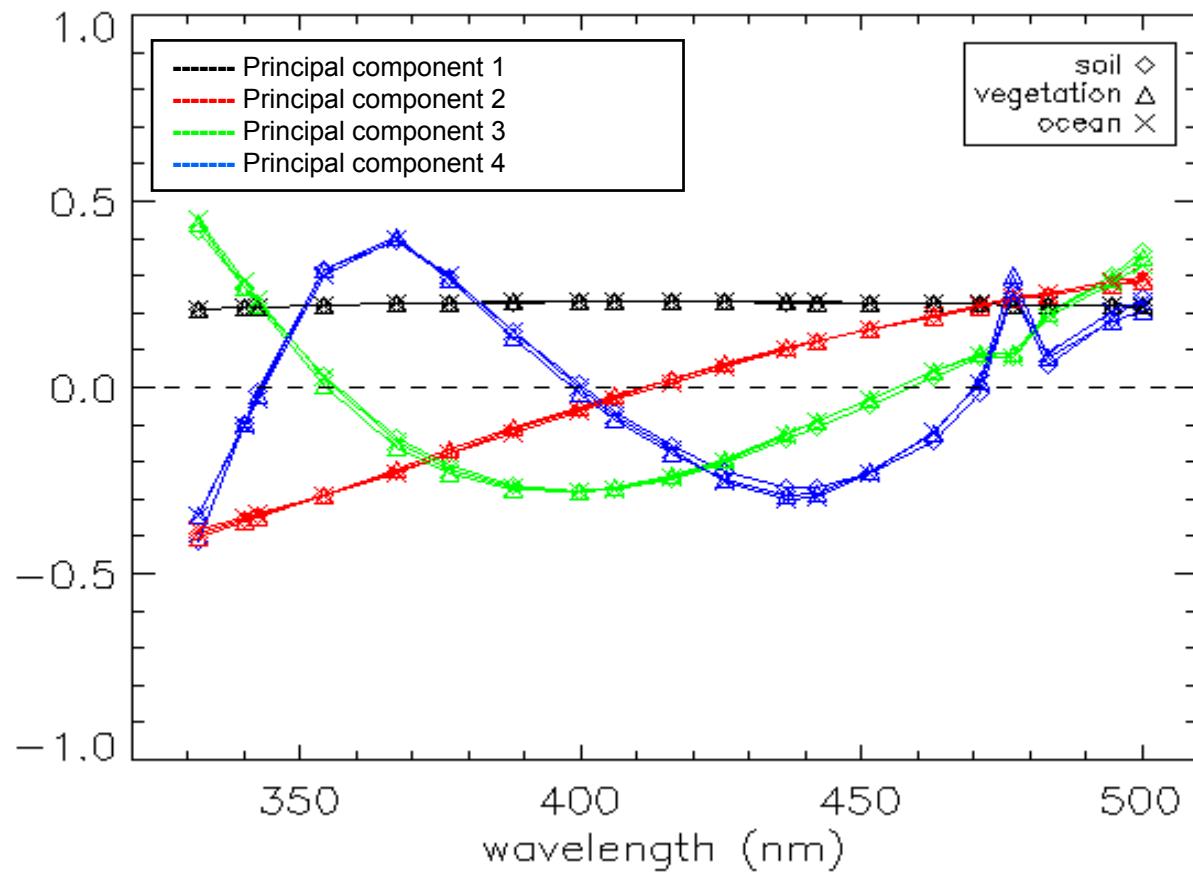
- Aerosol models (~250)
 - Biomass burning, Desert dust, Weakly absorbing
 - Aerosol Optical Depth (AOD) 0 – 5
 - Refractive Index various $m = n - ik(\lambda)$
 - Single Scattering Albedo (SSA) ... 0.8 – 1
 - Size Distribution various bimodal
 - Height of layer 1-5 km
- Cloud models
- Geometries $8\mu, 8\mu_0, 11\Delta\phi, \rightarrow \sim 700$
- Surface albedo (λ) ocean, soil, vegetation



Principal Components

$$R_{lm} = \sum_{k=1}^K W_{km} P_{kl} + \varepsilon$$

$$\begin{aligned}\mu_0 &= 0.6 \\ \mu &= 0.9 \\ \Delta\phi &= 20^\circ\end{aligned}$$

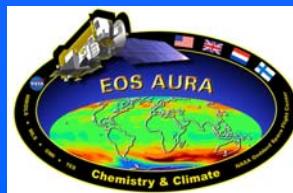
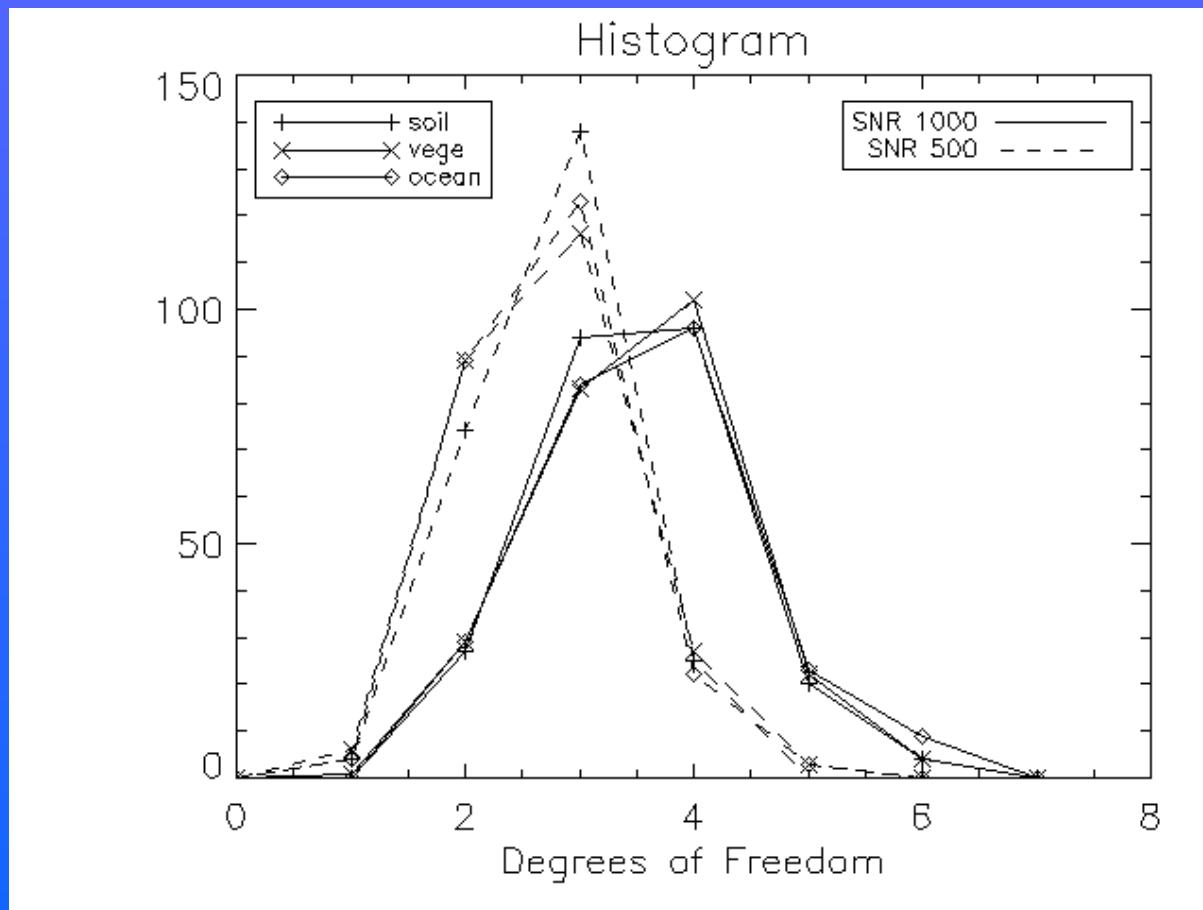


Degrees of Freedom of Signal

Surface albedo

$$R_{lm} = \sum_{k=1}^K W_{km} P_{kl} + \varepsilon$$

Soil/Veget.
 $\mu_0 = 0.6$
 $\mu = 0.9$
 $\Delta\phi = 20^\circ$

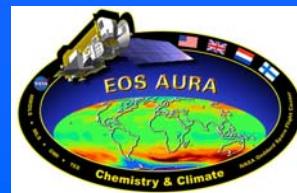
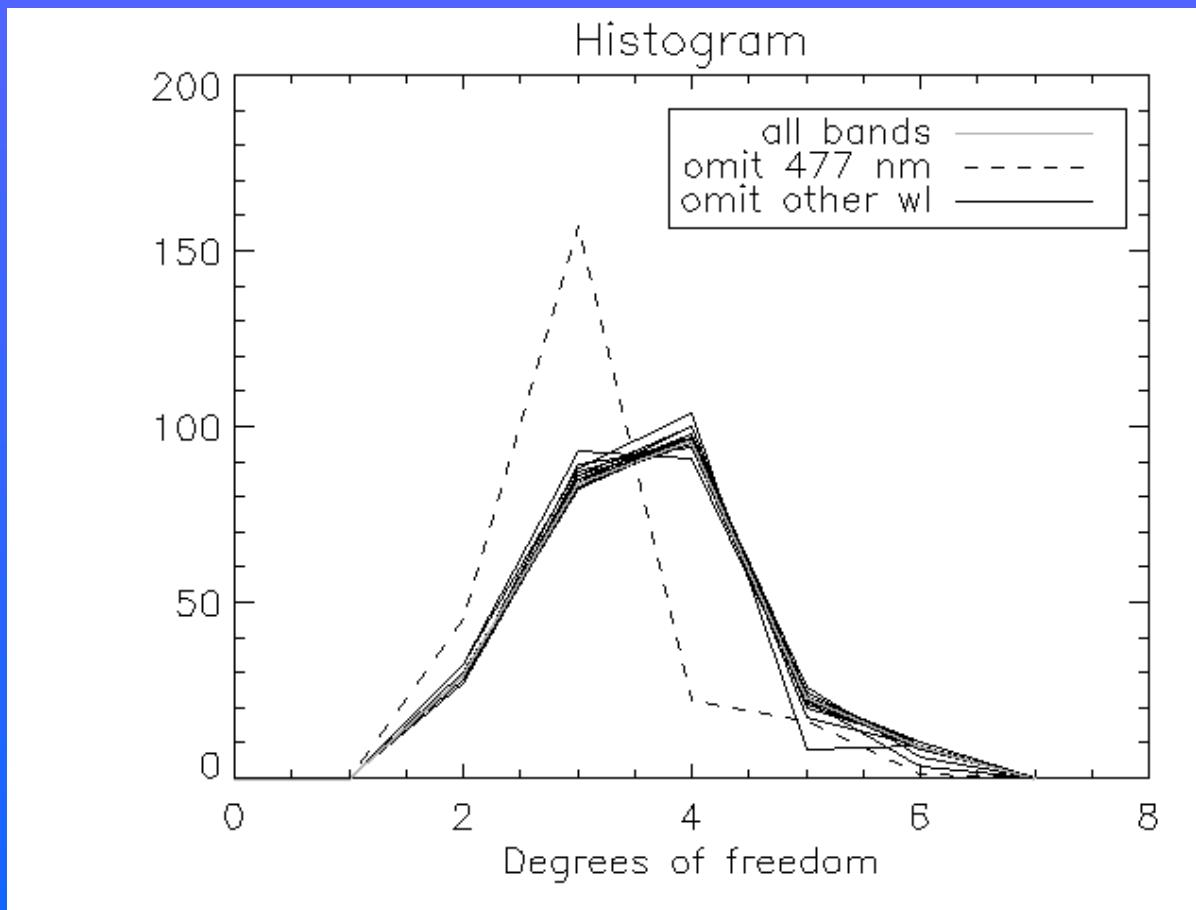


Degrees of Freedom od Signal

Wavelength Band Selection

$$R_{lm} = \sum_{k=1}^K W_{km} P_{kl} + \varepsilon$$

Soil/Veget.
 $\mu_0 = 0.6$
 $\mu = 0.9$
 $\Delta\phi = 20^\circ$
SNR=1000

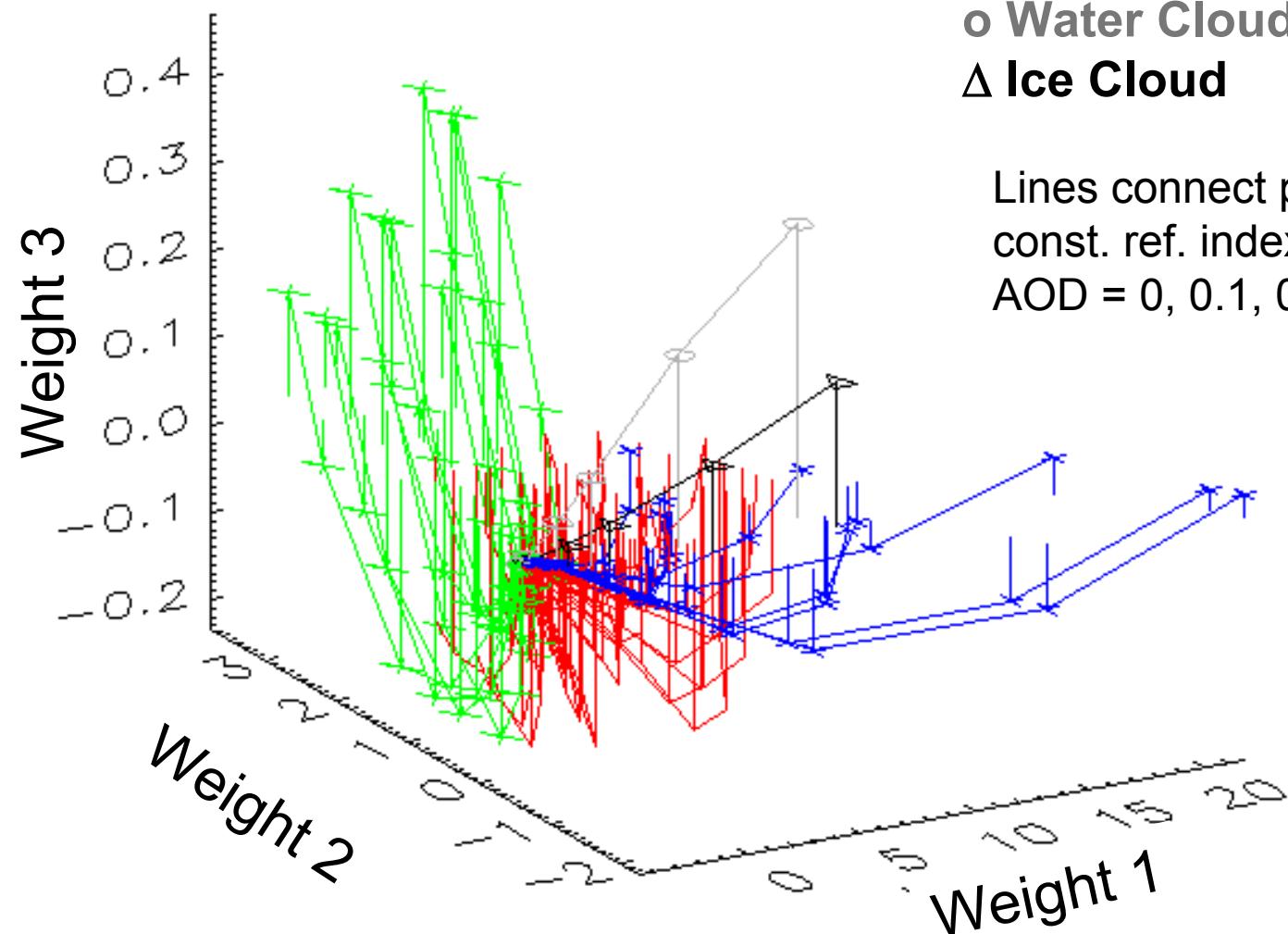


Soil/Veget.

$$\mu_0 = 0.6$$

$$\mu = 0.9$$

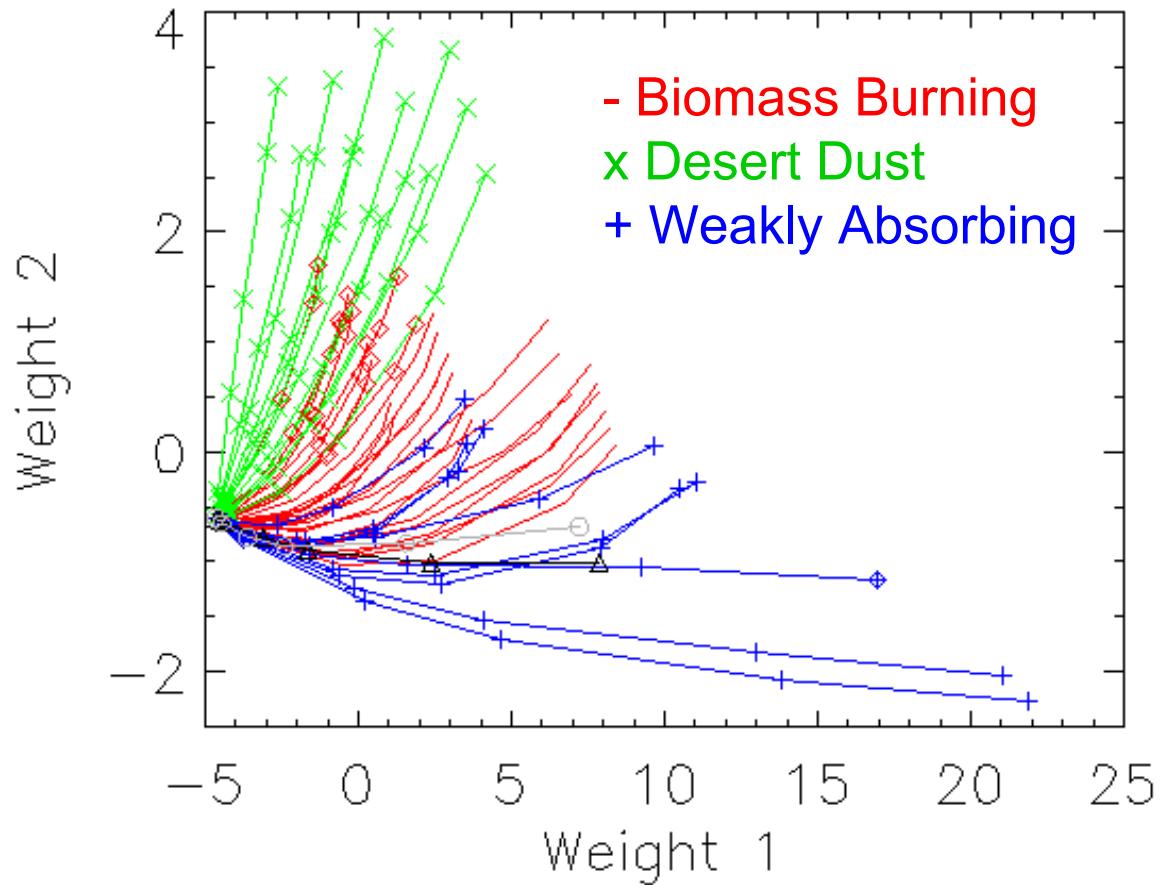
$$\Delta\phi = 20^\circ$$



- Biomass Burning**
- x Desert Dust**
- + Weakly Absorbing**
- o Water Cloud**
- △ Ice Cloud**

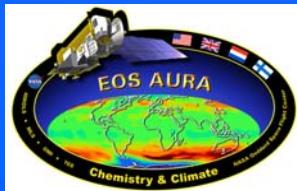
Lines connect points with
const. ref. index, height, size
AOD = 0, 0.1, 0.5 1.0, 2.5, 5.0

Distinguish Aerosol Types

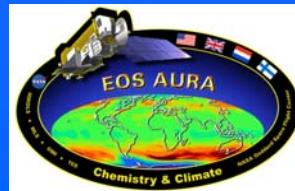
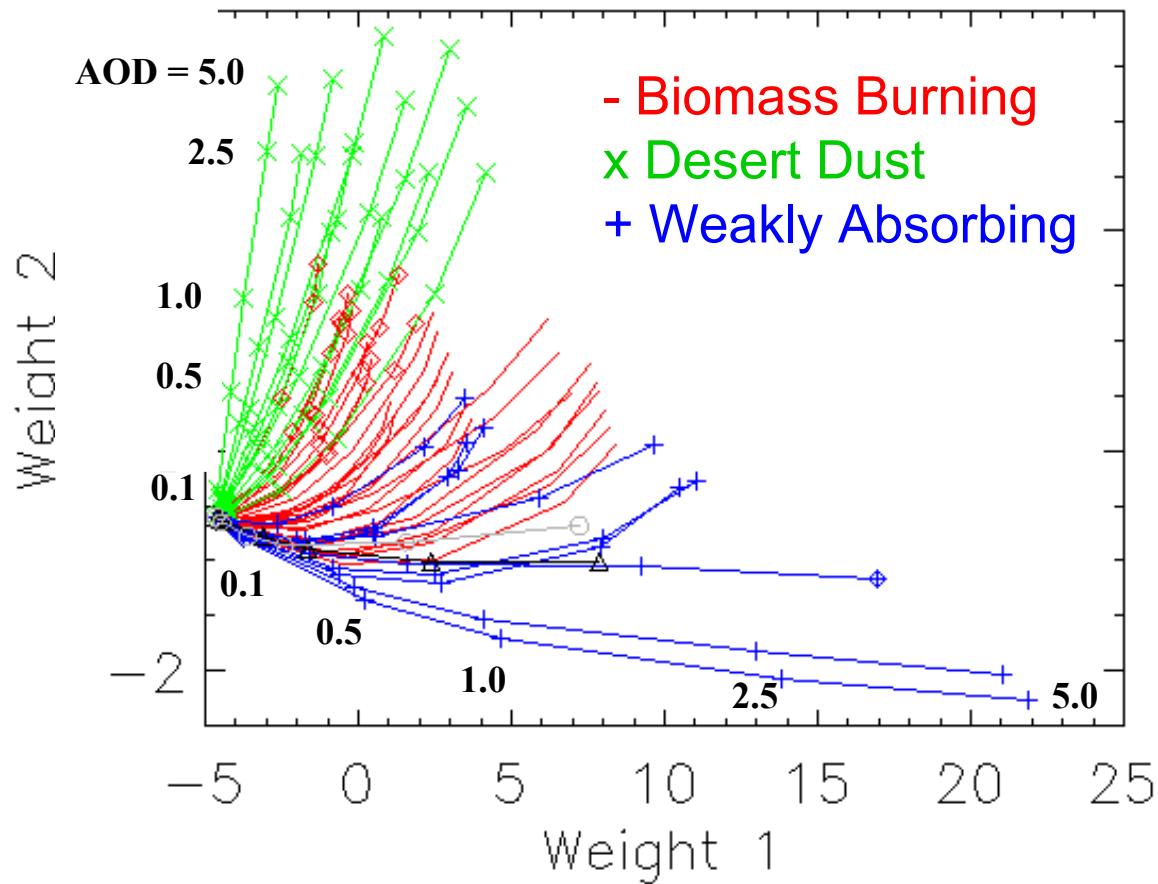


Information on Aerosol in OMI Measurements
Aura Science & Validation Team Meeting, September 2006
B.Veihelmann et al., KNMI

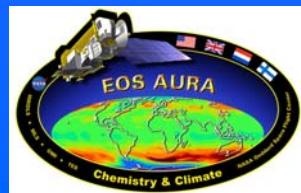
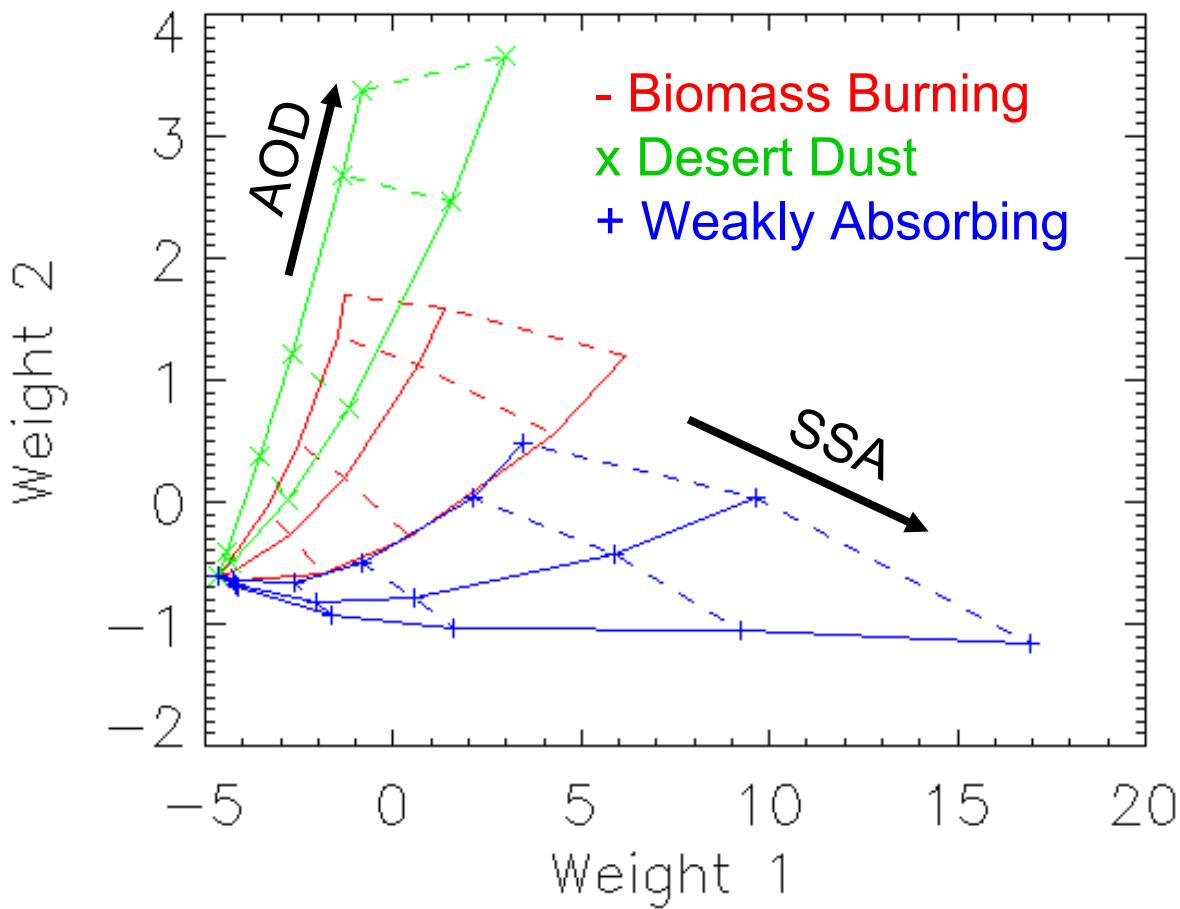
Slide 11



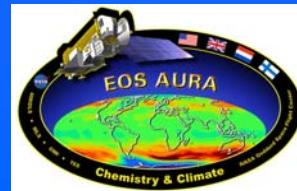
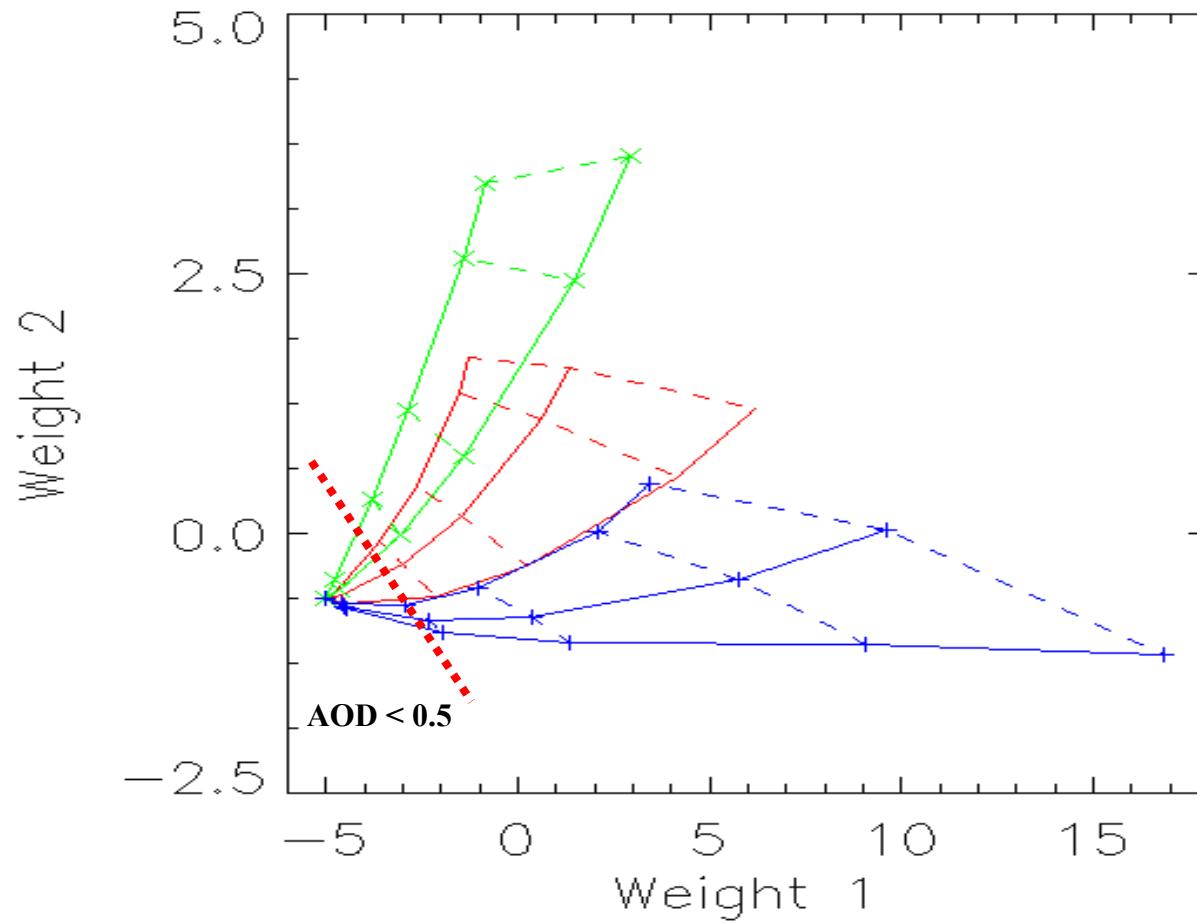
Distinguish Aerosol Types: $AOD \geq 0.5$



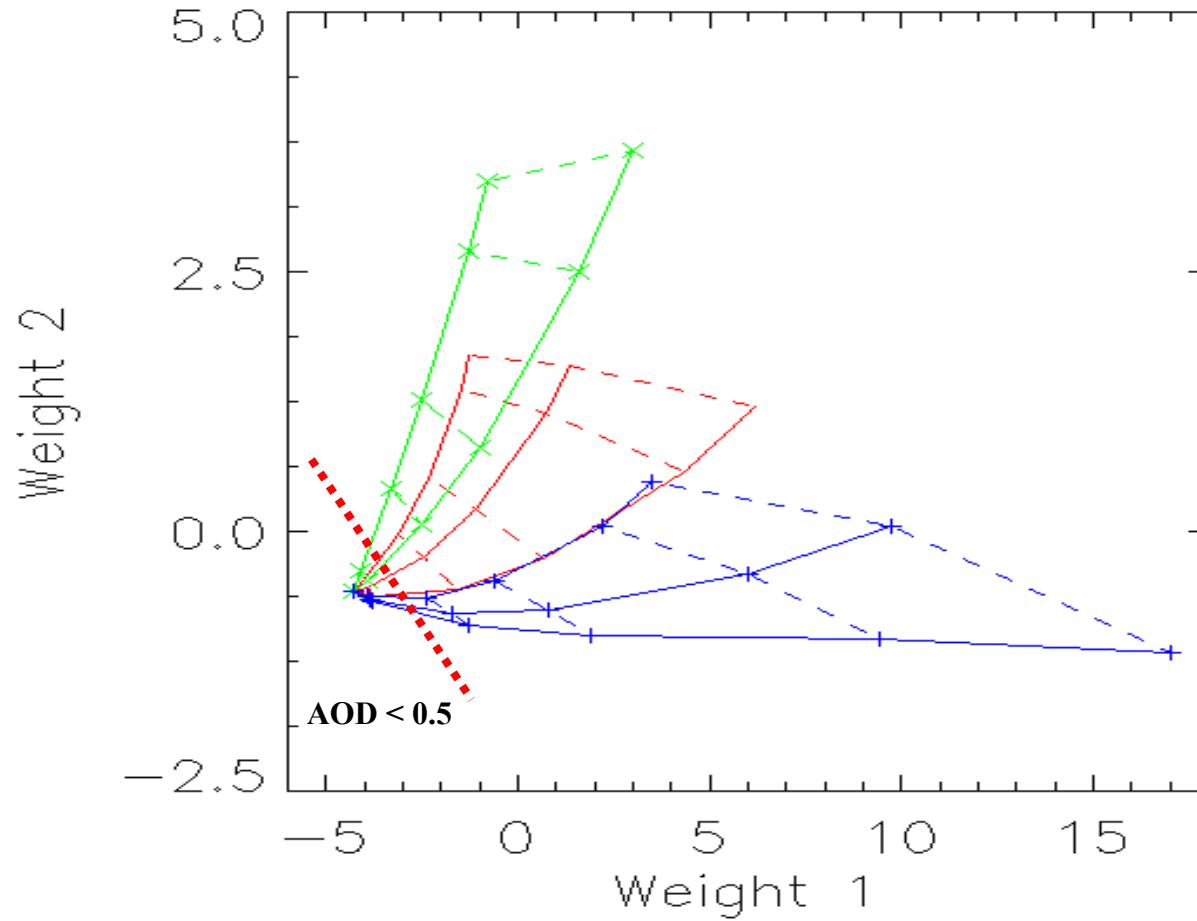
Separate AOD and SSA



Surface Albedo Error +/- 0.01

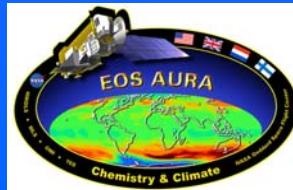


Surface Albedo Error +/- 0.01

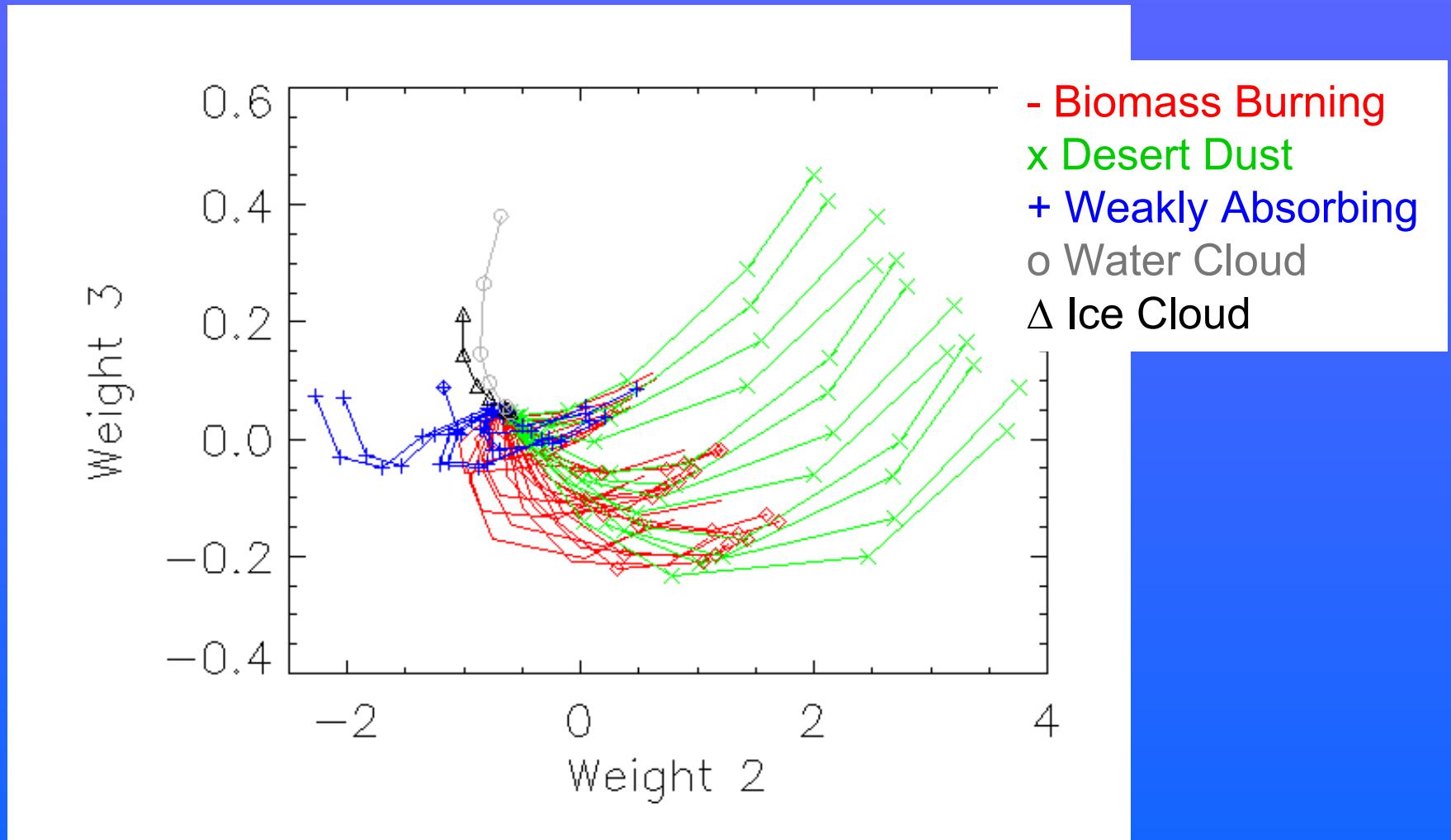


Information on Aerosol in OMI Measurements
Aura Science & Validation Team Meeting, September 2006
B.Veihelmann et al., KNMI

Slide 15

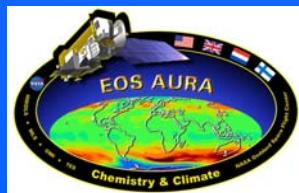


Distinguish Clouds: ≥ 3 DFS



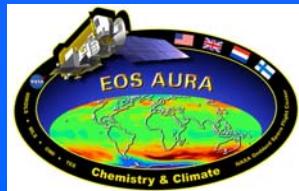
Information on Aerosol in OMI Measurements
Aura Science & Validation Team Meeting, September 2006
B.Veihelmann et al., KNMI

Slide 16



Conclusions

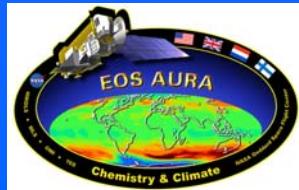
- Aerosol multi-wavelength algorithm 20 bands 331 - 500 nm
- Signal has 2 to 4 degrees of freedom
 - number insensitive to surface (ocean, soil, vegetation)
- 477 nm band adds information
 - O₂-O₂ absorption appears in 3rd PC and higher
- Distinguish Aerosol Types:
 - desert dust / weakly absorbing
 - some ambiguity biomass burning
- Separate AOD and SSA for absorbing aerosol
- Surface albedo error: minor impact for ADO ≥ 0.5
- Clouds can be distinguished if number of DFS ≥ 3



Backup Material

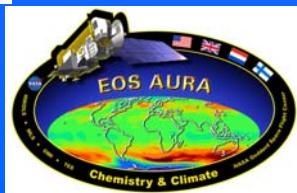
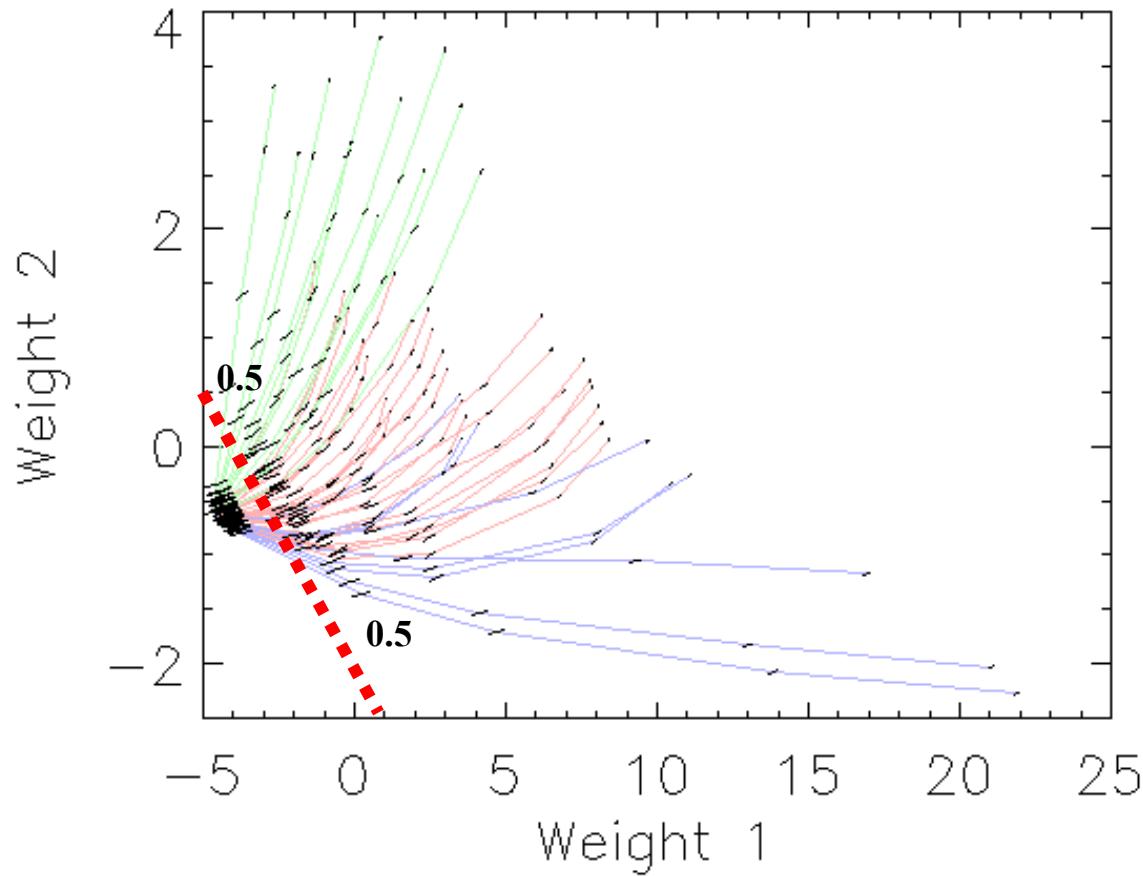
Information on Aerosol in OMI Measurements
Aura Science & Validation Team Meeting, September 2006
B.Veihelmann et al., KNMI

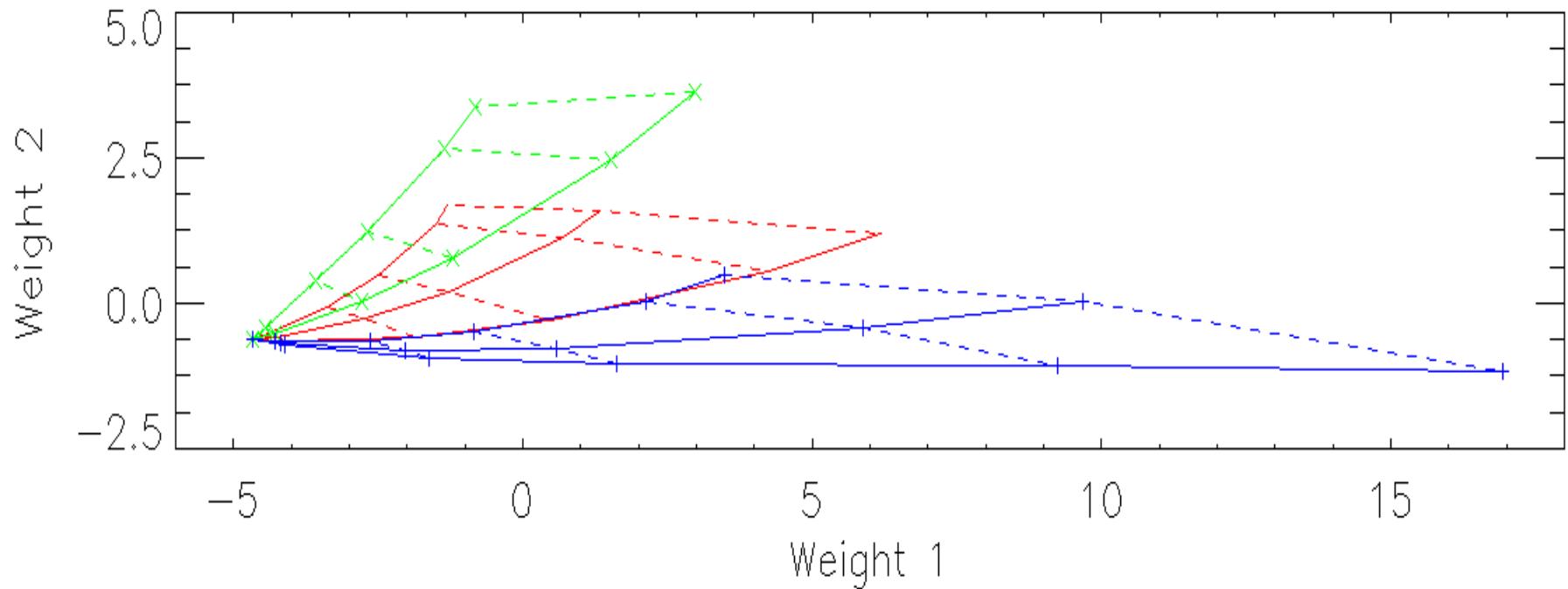
Slide 18



Surface Albedo Error +/- 0.01

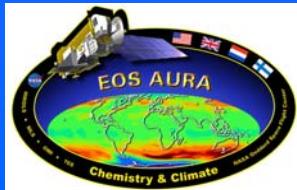
impact minor for AOD ≥ 0.5





Information on Aerosol in OMI Measurements
Aura Science & Validation Team Meeting, September 2006
B.Veihelmann et al., KNMI

Slide 20

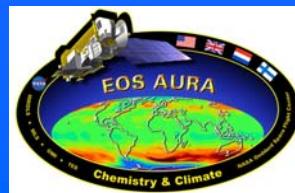
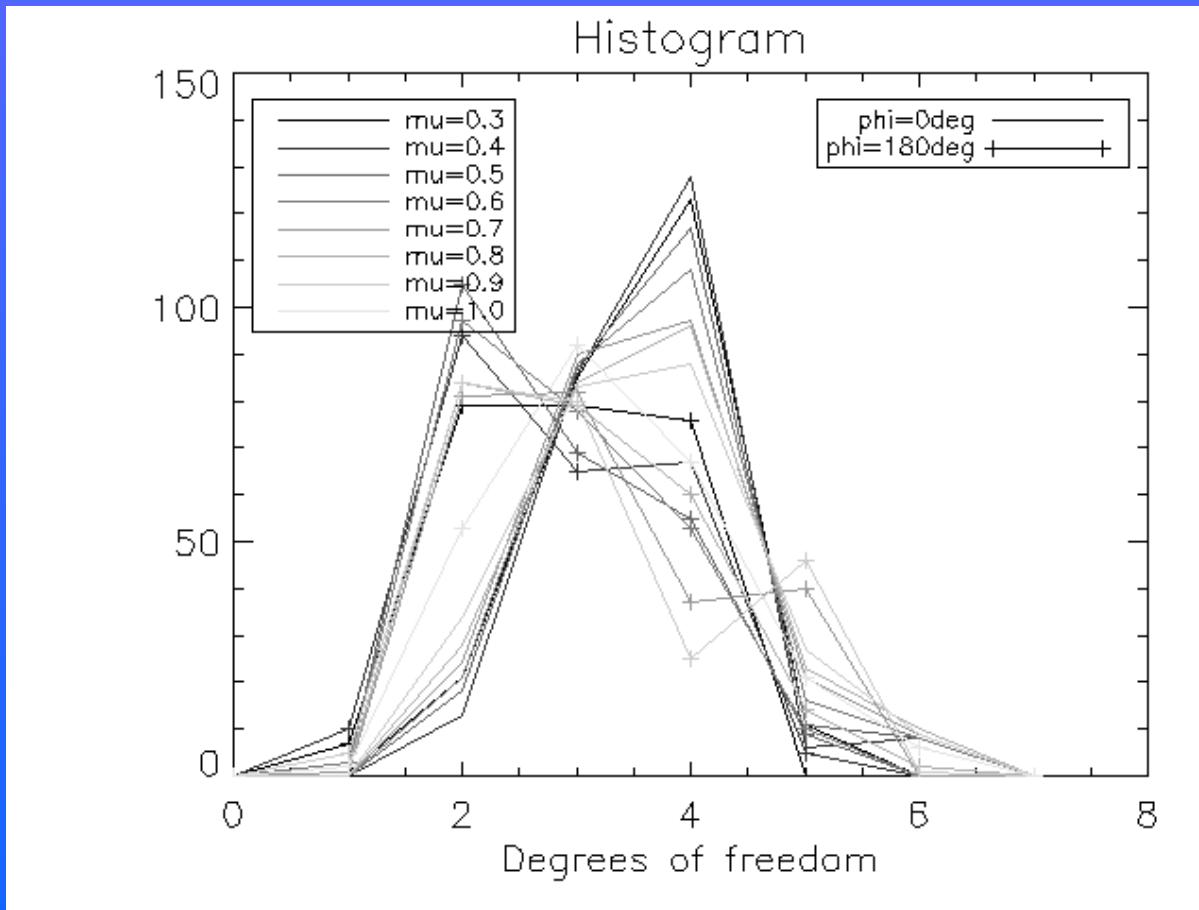


Degrees of Freedom of Signal

Geometry

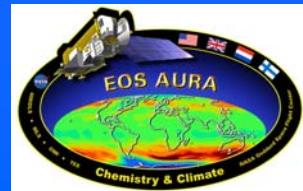
$$R_{lm} = \sum_{k=1}^K W_{km} P_{kl} + \varepsilon$$

Soil/Veget.
 $\mu_0 = 0.6$
SNR=1000



Outlook

- Non-spherical desert dust aerosol model
 - Spheroidal shape approximation
- Validation
 - AERONET ground based sunphotometer measurements
 - Other satellite instruments PARASOL...



Principal Component Analysis

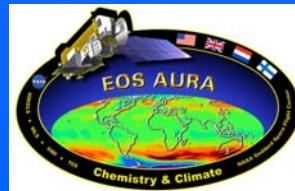
- P transforms R to coordinate system with **principal axes**
- Number of dimensions can be reduced to **K**

$$W_{km} = \sum_l P_{kl} R_{lm}$$

R_{lm} = Reflect.(λ ,model)

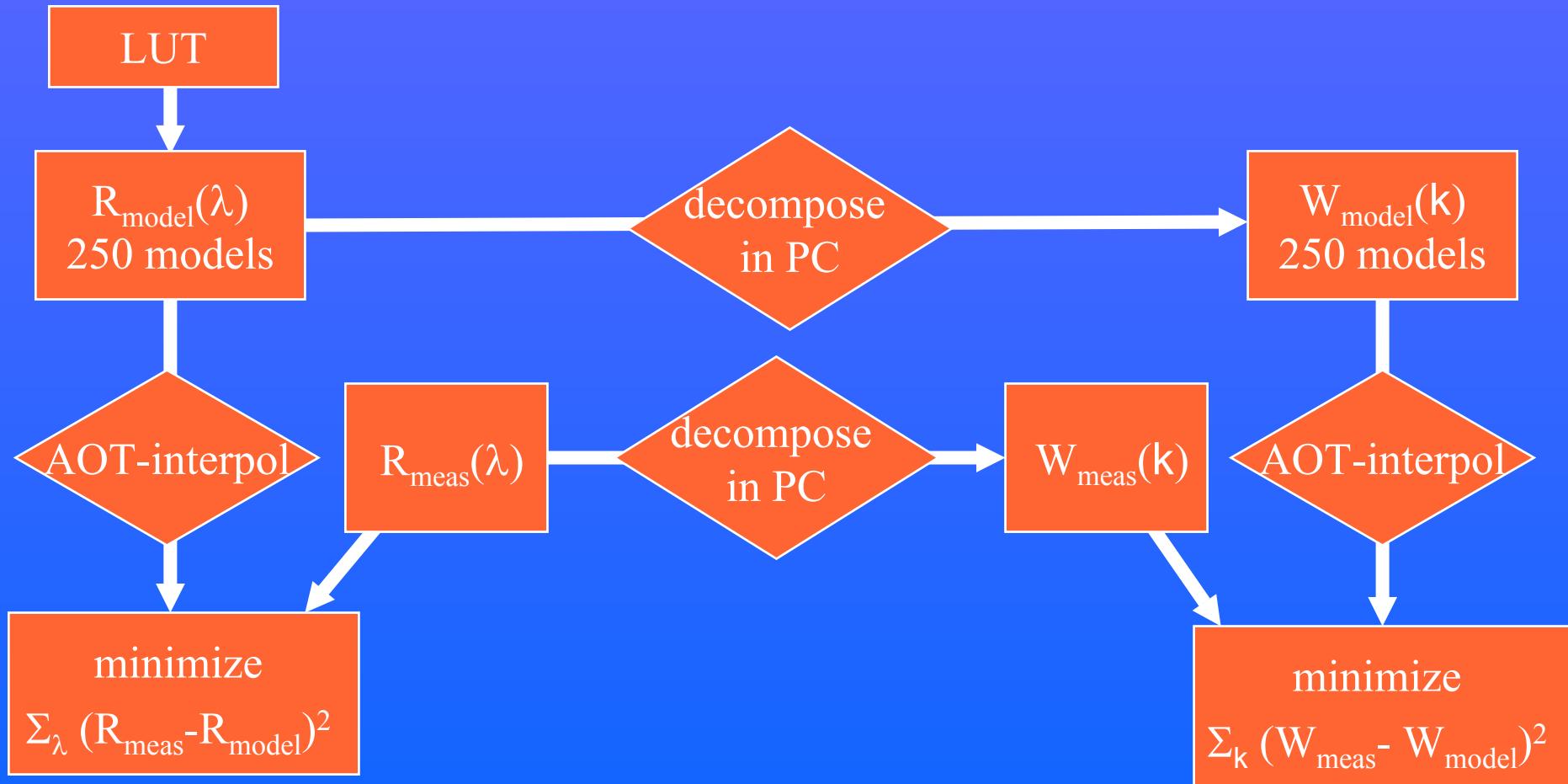
W_{km} = Weight (k,model)

$$R_{lm} = \sum_{k=1}^K W_{km} P_{kl} + \varepsilon$$



Nominal Retrieval

PCA-Retrieval



Information on Aerosol in OMI Measurements
Aura Science & Validation Team Meeting, September 2006
B.Veihelmann et al., KNMI

Slide 24

